

CAN THE CHIRALITY OF THE ISM BE MEASURED?

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Many moderately complex carbon-based molecules of the type associated with biological systems can exist in one of two mirror-image forms (left-handed and right-handed), which can be distinguished on the basis of their influence on the state of polarization of a light beam. Both forms are possible in nature; yet in living organisms it is invariably the rule that one of the two species predominates. This gives rise to a net "chirality". One possible explanation for the net chirality is that the early earth was somehow "seeded" from the ISM with an excess of chiral organic compounds which led to the development of life forms which are based on left-handed amino acids and right-handed sugars.

Molecular spectroscopy of the interstellar medium (ISM) has revealed a complex variety of molecular species similar to those thought to have been available in the oceans and atmospheres of the earth at the time life formed. The detection of such molecules demonstrates the generality of the chemical processes occurring in both environments. If this generality extends to the processes which produce chirality, it may be possible to detect a net chirality in the ISM. This is of particular interest because determining whether or not net chirality exists elsewhere in the universe is an essential aspect of understanding how life developed on earth and how widely distributed it might be. We report preliminary results of a feasibility study to determine whether or not a net chirality in the ISM can be measured.

A net excess of chiral molecules, i.e., a solution of one of the two enantiomeric forms, can affect the transmittance of polarized light in the following ways. The complex index of refraction, $m=n+ik$, of the material through which the light passes will cause differing effects for the left and right handed components of circularly polarized light (CPL). In the infrared, the absorption, which is governed by the imaginary component, k , can be greater for either the left or right hand component of CPL if there is a net chirality. Differences in the relative absorption of the right and left hand CPL components by enantiomerically pure solutions has been demonstrated in the laboratory at infrared wavelengths and is referred to as vibrational circular dichroism (VCD). This effect has been successfully detected by Freedman and Naife (1986) in the study of relatively simple molecules similar to the types of molecules likely to exist in the interstellar medium. However, the effect is a small one for the molecules which have been tested to date and further work is required to estimate the magnitude of such an effect for molecules which would be of astrophysical interest.

A related effect of chiral molecules on polarized light is governed by the real compo-

nent of the complex index of refraction, n . As the two components of CPL propagate through a medium consisting primarily of either right or left handed molecules, the configuration of the molecule presented to the right hand component of CPL will differ from that presented to the left hand component of CPL. This condition translates to a situation where one component of the light is able to traverse the medium faster than the other resulting in an overall phase shift between the two components. In the case of linearly polarized light, which can be thought of as a superposition of equal amounts of right and left hand circularly polarized light with a fixed phase relation, such a phase shift would cause a rotation in the plane of polarization. This effect would be detectable as a change in the plane of polarization, relative to that at adjacent wavelengths, in the appropriate spectral bands of chiral molecules.

Laboratory studies of both the VCD effect and the rotation of the polarization plane of linearly polarized light have not been carried out for molecules of astrophysical interest. However, it is encouraging to note that at the present time several groups are studying VCD in order to better understand molecular structure. Ideally one would hope to find a noticeable effect among simple molecular structures since it is those types of molecules that are likely to be present in the ISM. Freedman *et al.* (1987) report the detection of VCD effects in duterated C_2OH_4 , a simple molecule that may help to predict the magnitude of the effect of VCD that could be expected for molecules likely to exist in space. In addition to analyzing the VCD effect of such molecules, we plan to investigate the effective rotation of linearly polarized light through enantiomerically pure solutions of simple molecules. If the effect is significant, one could look for the effect in astrophysically interesting molecules along lines of sight where strong background sources of linearly polarized infrared light can be seen through molecular clouds. The infrared portion of the spectrum is more suitable than the visible region for such a study since the longer wavelength infrared light from young stellar objects can penetrate the high molecular density of the material surrounding them. Nature has provided linearly polarized background sources known as infrared reflection nebulae (Werner *et al.* 1983; Pendleton *et al.* 1986). Infrared reflection nebulae are regions of high linear polarization caused by the scattering of light from a nearby, dust embedded pre-stellar object. These regions are seen through large column densities of dust and gas which could contain molecules of interest to this study. If laboratory results identify candidate chiral molecules that might exist in the ISM, the next step in this feasibility study will be to estimate the detectability of the chiral signature in astrophysical environments.

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